Chapter 2. DATA ANALYSIS AND COMPLIANCE WITH THE CRITERIA.

1. General. All data obtained in the dynamic tests should be reviewed for errors. Baseline drift, "ringing," and other common electronic instrumentation problems should be detected and corrected before the tests. Loss of data during the test is readily observed in a plot of the data vs. time and is typically indicated by sharp discontinuities in the data, often exceeding the amplitude limits of the data collection system. If these occur early in the test in essential data channels, the data should be rejected and the test repeated. If they occur late in the test, after the maximum data in each channel has been recorded, the validity of the data should be carefully evaluated, but the maximum values of the data may still be acceptable for the tests described in this AC. The HIC does not represent a maximum data value, but represents an integration of data over a varying time base. The head acceleration measurements used for that computation should not be accepted if errors or loss of data are apparent in the data at any time from the beginning of the test until the ATD and all test articles are at rest after the test.

2. Impact pulse shape. Data for evaluating the impact pulse shape are obtained from an accelerometer that measures the acceleration in the direction parallel to the line of inertial response shown in Figure 1 of this AC. The impact pulse intended for the tests discussed in this AC has a symmetrical (isosceles) triangular shape. Since this ideal pulse is considered a minimum test condition, it is possible to evaluate the actual test pulse by comparing it with the ideal triangular pulse. The ideal pulse can be drawn to scale on the data plot of the test sled or carriage acceleration vs. time. The test pulse is acceptable if the plotted data are equal to or greater than the ideal impact pulse. This method can lead to a practical necessity of exceeding the ideal pulse by a significant degree, unless the test facility has precise control in generating the test pulse. To avoid that problem, an alternate graphic technique may be used to evaluate test impact pulse shapes that are not precise isosceles triangles. A graphic technique is contained in Chapter 4, Paragraph 1 of this AC.

3. Head Injury Criterion (HIC). Data for determining the HIC need to be collected during the tests discussed in this AC only if the ATD's head is exposed to secondary impact. The HIC is a method for defining an acceptable limit; i.e., the maximum values of the HIC should not exceed 1,000 for head impact against broad interior surfaces in a crash. The HIC is reported as the maximum value, and the time interval during which the maximum value occurs is also given. Most facilities will make this computation if requested. The HIC is calculated by computer-based data analysis systems because manual attempts to use this method with real data are likely to be tedious. The HIC is calculated according to the following equation:

$$HIC = (t_2 - t_1)\left[(1/(t_2 - t_1))\int_{t_1}^{t_2} a(t)dt\right]^{2.5}_{MAX}$$

Where: t_1 and t_2 are any two points in the time range during the head impact. The range should not exceed 0.050 seconds, and a(t) is the resultant head acceleration at the center of gravity (expressed in g's) during the head form impact.

a. Data collection. The HIC is commonly based on data obtained from three mutually perpendicular accelerometers installed in the head of the ATD in accordance with the ATD specification. Data from these accelerometers are obtained using a data system conforming to Channel Class 1,000 as described in SAE Recommended Practice J211. For the tests discussed in this AC (both ATD and head form), only the data taken during secondary head impact with the aircraft interior need be considered. Head impact is often indicated in the data by a rapid change in the magnitude of the acceleration. Alternately, a film of the test may show head impact which can be correlated with the acceleration data by using the time base common to both electronic and photographic instrumentation, or simple contact switches on the impacted surface can be used to define the initial contact time.

b. HIC methodology. The following discussion outlines the basic method for computing the HIC. The magnitude of the resultant acceleration vector obtained from the three accelerometers is plotted against time. Then, beginning at the time of initial head contact (t_1), the average value of the resultant acceleration is found for each increasing increment of time ($t_2 - t_1$), by integrating the curve between the range of t_1 and t_2 and then dividing the integral value by the time ($t_2 - t_1$). This calculation should use all data points provided by the minimum 8,000 samples per second digital sampling rate for the integration. However, the maximizing time intervals need be no more precise than 0.001 seconds. The average values are then raised to the 2.5 power and multiplied by the corresponding increment of time ($t_2 - t_1$). This procedure is then repeated, increasing t_1 by 0.001 seconds for each repetition. The maximum value of the set of computations obtained from this procedure is the HIC. The procedure may be simplified by noting that the maximum value will only occur in intervals where the resultant magnitude of acceleration at t_1 is equal to the resultant magnitude of acceleration at t_2 and when the average resultant acceleration in that interval is equal to 5/3 times the acceleration at t_1 or t_2.

c. Limitations. HIC does not consider injuries that can occur from contact with surfaces having small contact areas or sharp edges, especially if those surfaces are relatively rigid. These injuries can occur at low impact velocities, and are often described as "cosmetic" injuries; however, they can involve irreversible nerve damage and permanent disfigurement. While there is no generally accepted test procedure to provide quantitative assessment of these injuries, a judgmental evaluation of soft tissue injuries can be made by assessing tears or cuts in a synthetic skin placed over the ATD's head or a head form during the test. Synthetic skins are discussed in the Society of Automotive Engineers Information Report SAE J202, Synthetic Skins for Automotive Testing.

4. Impact velocity. Impact velocity can be obtained by measurement of a time interval and a corresponding sled displacement occurring just before or after (for acceleration facilities) the test impact, and then dividing the displacement by the time interval. When making such a computation, the possible errors of the time and displacement measurements should be used to calculate a possible velocity measurement error, and the test impact velocity should exceed the velocity shown in Figure 1 by at least the velocity measurement error. If the sled is changing acceleration during the immediate pre-impact interval, or if the facility produces significant rebound of the sled, the effective impact velocity can be determined by integrating the plot of sled acceleration vs. time. If this method is used, the sled acceleration should be measured in accordance with Channel Class 180 requirements.

5. Upper torso restraint system load. The maximum load in the upper torso restraint system webbing can be obtained directly from a plot or listing of webbing load transducer output. If a three-axis load transducer, fixed to the test fixture, is used to obtain these data, the data from each axis should be combined to provide the resultant vector magnitude. If necessary, corrections should be made for the internal mass of the transducer and the fixture weight it supports. This correction will usually be necessary only when the inertial mass or fixture weight is high or when the correction becomes critical to demonstrate that the measurements fall below the specified limits.

6. Compressive load between the pelvis and lumbar column. The maximum compressive load between the pelvis and the lumbar column of the dummy can be obtained directly from a plot or listing of the output of the load transducer at that location. Since most load cells will indicate tension as well as compression, care should be taken that the polarity of the data has been correctly identified.

7. Retention of upper torso restraint straps. Retention of the upper torso restraint webbing straps on the ATD's shoulders can be verified by observation of photometric or documentary camera coverage. The webbing should remain on the sloping portion of the ATD's shoulder until the ATD rebounds after the test impact and the upper torso restraint straps are no longer carrying any load. The webbing straps should not bear on the neck or side of the head and should not slip to the upper rounded portion of the upper arm during that time period.

8. Retention of lap safety belt. Retention of the lap safety belt on the occupant's (ATD) pelvis can be verified by observation of photometric or documentary camera coverage. The lap safety belt should remain on the ATD's pelvis, bearing on or below each prominence representing the anterior superior iliac spines, until the ATD rebounds after the test impact and the lap safety belt becomes slack. If the lap safety belt does not become slack throughout the test, the belt should maintain the proper position throughout the test. Movement of the lap safety belt above the prominence is usually indicated by an abrupt displacement of the belt into the ATD's soft abdominal insert which can be seen by careful observation of photo data from a camera located to provide a close view of the belt as it passes over the ATD's pelvis. This movement of the belt is sometimes indicated in measurements of lap safety belt load (if such measurements are made) by a transient decrease or plateau in the belt force, as the belt slips over the prominence, followed by a gradual increase in belt force as the abdominal insert is loaded by the belt. Retention of the lap safety belt can also be verified by "submarining indicators" located on the ATD's pelvis. These transducers are essentially a series of small, uncalibrated load cells placed in or above the rim of the ATD's pelvis without changing its essential geometry. They indicate the position of the lap safety belt by producing an electrical signal when they are under load from the belt.

9. Femur load. Measuring femur loads is not required by the rotorcraft standards. If a seat is installed in an aircraft in a manner that will expose the system to loads from an occupant seated behind the seat system as well as the occupant seated in the seat system, the tests discussed in this AC should be conducted in a manner to demonstrate that the system will perform properly under the combined loading. For example, Test 2 should be conducted with at least two rows of seats in place, as the seats in the first row carry the loads from the occupants in the first row, as well as the leg kick loads from the second row (also noted in 3b(1) of this AC).

10. Seat attachment. Documentation that the seat and restraint system has remained attached at all points of attachment should be provided by still photographs that show the intact system components in the load path between the attachment points and the occupant.

11. Seat deformation. Occupant seats evaluated in the tests discussed in this AC can deform permanently, either due to the action of discrete (impact) energy absorber systems included in the design or due to residual plastic deformation of their structural components. If this deformation is excessive, it could impede emergency evacuation. Each seat design may differ in this regard and should be evaluated according to its unique deformation characteristics. Permanent seat deformations are measured on the critically loaded seat subsequent to conduct of the tests required in §§ 27.562 and 29.562. The seat deformation is measured subsequent to completion of the dynamic tests and, where applicable, release of the applied pre-test floor deformation.

a. Seats. The following post-test deformations and limitations regarding emergency egress and access to exits may be used for showing compliance with § 29.785(j):

(1) Forward or Rearward Directions. The forward or rearward deformations should not exceed a maximum of 4.0 inches (100 mm). In addition, the clearance between undeformed seat rows, measured as shown in Figure 5 (Dimension A), should be a minimum of 9.0 inches, except where seat rows lead to Type III or IV exits, where it should be a minimum of 11.0 inches. For seats with deformations exceeding 4.0 inches, the undeformed clearances between seats should be increased accordingly. In addition, at seat rows leading to Type III or IV exits, a minimum of 20 inches clearance, measured above the arm rests, must be maintained between adjacent seat rows. This measurement may be made with the seat backs returned, using no more than original seat back breakover forces, to their pretest upright or structurally deformed position. At other seat rows, the most forward surface of the seat back must not deform to a distance greater than one half of the original distance to the forwardmost hard structure on the seat (see Figure 6).

(2) Downward Direction. There is no limitation on downward deformation, provided it can be demonstrated that the feet or legs of occupants seated aft would not be entrapped. Additionally, the seat bottom rotational deformation from the horizontal, measured at the centerline of each seat pan, should not exceed 20° forward (pitch down) or 35° aft (pitch up). This measurement should be made between the fore and aft extremities of the seat pan structure, considering the final position of the seat pan structure. In no case should rotation of the seat pan cause entrapment of the occupant.

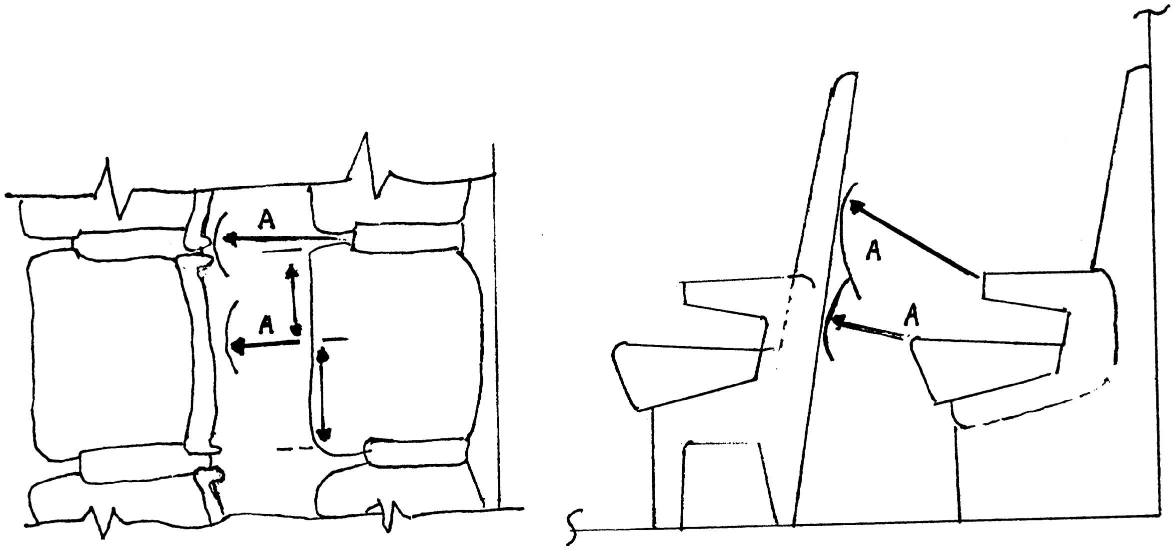
(3) Sideward Direction.

(i) The deformed seat should not encroach more than 1.5 inches (40 mm) into the required space for longitudinal aisle at heights up to 25 inches (635 mm) above the floor. Determine which parts of the seat are at what heights prior to testing.

(ii) The deformed seat should not encroach more than 2.0 inches (50 mm) into the longitudinal aisle space at heights 25 inches (635 mm) or more above the floor.

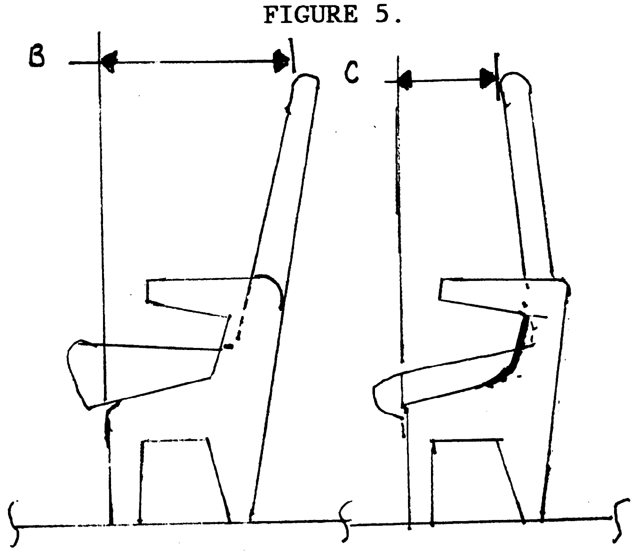
(4) Additional Considerations. In addition, none of the above deformations must permit the seat to:

(i) Affect the operation of any emergency exit or encroach into an emergency exit opening for a distance from the exit not less than the width of the narrowest passenger seat installed except as stated in § 29.813(c)(2).



Measurement to be taken over full width of seat bottom cushion.

FIGURE 5.



Pre-test Condition Posttest Condition
Dimension "C" must be at least 50% of Dimension "B"

FIGURE 6.

(ii) Encroach into any required passageway to large exits, § 29.813(a) and (b).

(iii) Encroach more than 1.5 inches into any cross aisle or evacuation (flight attendant) assist space for certain exits.

b. Stowable Seats. Stowable seats, if used, should stow post-test and remain stowed without projecting into any required passageways. In addition, they should not project more than 1.5 inches into any flight attendant assist space or cross-aisle.

(1) Seats that are Stowed Manually. A post-test stowage force no greater than 10 pounds (22kg) above the original stowage force may be used to stow the seat.

(2) Seats that Stow Automatically. For a seat that may interfere with the opening of any exit, it shall automatically retract to a position that does not interfere with the exit opening as prescribed in §29.807. For determining encroachment into passageways, cross-aisles, and assist spaces, a posttest stowage force no greater than 10 pounds (22kg), applied at a single point, may be used to assist automatic retraction.

Chapter 3. TEST DOCUMENTATION.

1. General. The tests discussed in this AC should be documented in reports describing the test procedures and results. The test proposal, a description of the required tests, approved by the FAA should be referenced in the test report and contain the following:

a. Facility data.

(1) The name and address of the test facility performing the tests.

(2) The name and telephone number of the individual at the test facility responsible for conducting the tests.

(3) A brief description and/or photograph of each test fixture.

(4) The date of the last instrumentation system calibration and the name and telephone number of the person responsible for instrumentation system calibration.

(5) A statement confirming that the data collection was done in accordance with the recommendations in this AC or a detailed description of the actual calibration procedure used and technical analysis showing equivalence to the recommendations of this AC (Chapter 1, Paragraph 2c(1)).

(6) Manufacturer, governing specification, serial number, and test weight of ATD used in the tests, and a description of any modifications or repairs performed on the ATD which could cause them to deviate from the specification.

(7) A description of the photographic-instrumentation system used in the tests (Chapter 1, paragraph 2c(2)).

b. Seat restraint system data.

(1) Manufacturers name and identifying model numbers of the seat restraint system used in the tests, with a brief description of the system, including identification and a functional description of all major components and photographs or drawings as applicable.

(2) For unsymmetric systems, an analysis supporting the selection of most critical conditions used in the tests.

2. Test Proposal or Plan and Description. The description of the test should be documented in enough detail so that the tests could be reproduced by following the guidance given in the report. The procedures outlined in this AC can be referenced in the report but should be supplemented, as necessary, to describe the unique conditions of the individual seat design.

a. Pertinent dimensions and other details of the installation not included in the drawings of the test items should be provided. This can include footrests, restraint system webbing guides and restraint anchorages, "interior surface" simulations, bulkhead or sidewall attachments for seats or restraints, etc.

b. The floor deformation procedure, guided by goals of most critical loading for the test articles, should be documented.

c. Placement and characteristics of electronic and photographic instrumentation chosen for the test, beyond that information provided by the facility, should be documented. This can include special targets, grids or marking used for interpretation of photodocumentation, and transducers and data channel characteristics for lap belt loads, floor reaction forces, or other measurements beyond those discussed in this AC.

d. Any unusual or unique activity or event pertinent to conducting the test should be documented. This could include use of special "breakaway" restraints or support for the ATD's, test items or transducers, operational conditions or activities such as delayed or aborted test procedures, and failures of test fixtures, instrumentation system components or ATD.

3. Test results report. The documentation should include copies of all test results, analysis, and conclusions. As a minimum, the following should be documented:

a. Impact pulse shape (Chapter 2, paragraph 2).

b. HIC results for all ATD exposed to secondary head impact with interior components of the rotorcraft (Chapter 2, paragraph 3), or head strike paths and velocities if secondary head impact is likely for future use in unique interiors (Chapter 1, paragraph 3b).

c. Impact velocity (Chapter 2, paragraph 4).

d. Upper torso restraint system load if applicable (Chapter 2, paragraph 5).

e. Compressive load between the pelvis and the lumbar column (Chapter 2, paragraph 6).

f. Retention of upper torso restraint straps if applicable (Chapter 2, paragraph 7).

g. Retention of lap safety belt (Chapter 2, paragraph 8).

h. Femur thigh loads, optional measurement.

i. Seat attachment (Chapter 2, paragraph 10).

j. Seat deformation (Chapter 2, paragraph 11).

k. Seat attachment reaction time histories (Chapter 4).

4. Dynamic Impact Test - Pass/Fail Criteria: The dynamic impact tests should demonstrate that:

a. The seat structure remains intact that is attached to the tracks or fittings, etc.

b. The occupant retention system is capable of carrying the dynamic loads.

c. The seat permanent deformations are within defined limits and will not significantly impede an occupant from releasing the torso restraints, standing and exiting the seat.

d. If the ATD's head is exposed to impact during the test, a HIC of 1,000 is not exceeded. Data may be obtained for use with other unique installations.

e. Where upper torso restraint straps are used, tension loads in individual straps do not exceed 7.78 kN (1,750 lbs.) If dual straps are used for restraining the upper torso, the total strap tension load does not exceed 8.90 kN (2,000 lbs.).

f. The maximum compressive load measured between the pelvis and the lumbar column of the (ATD) does not exceed 6.67 kN (1,500 lbs.).

g. Each upper torso restraint strap remains on the ATD shoulder during impact.

h. The pelvic restraint remains on the ATD pelvis during impact.

Chapter 4. PROCEDURES FOR EVALUATING IMPACT PULSE SHAPES.

1. Acceptable Evaluation Method. An acceptable method to evaluate the pulse shape should use the following steps:

a. Extend the calibration baseline (zero G) through the plot of test sled or carriage acceleration vs. time.

b. Locate the maximum acceleration (G_p) indicated on the plot.

c. Construct reference lines parallel to the baseline at levels of 0.1 G_p, 0.9 G_p, and 1.0 G_p.

d. Construct an onset line through the intersection points of the 0.1 G_p and 0.9 G_p reference lines with the increasing (onset) portion of the data plot. The data plot should not return to zero G between the two points selected.

e. Locate the intersection points of the onset line with the baseline and with the 1.0 G_p reference line. The interval between these two points, measured along the time axis of the data plot, is considered the rise time (t_r) of the test impact pulse.

f. The rise time of the test impact pulse should not exceed the value of (t_r) given in Figure 1 for each test.

g. The area under the data plot curve within the rise time of the test impact pulse should represent at least one half of the impact velocity given in Figure 1 for each test. If the value of peak acceleration measured in the test exceeds the level given in Figure 1 by no more than 10 percent, the pelvis to lumbar spinal column force and the upper torso restraint force measured in the test may be adjusted by multiplying the measured values by the ratio of the peak acceleration given in Figure 1, divided by the measured peak acceleration, if necessary.

h. The magnitude of G_p should equal or exceed the minimum G given in Figure 1 for each test.

i. The area under the data plot curve from the intersection point of the onset line and the zero G baseline and a time not more than twice the appropriate rise time specified in Figure 1, plus 30 percent of the rise time later, should represent at least the impact during the test.

2. Transport Airplane Impact Pulse and Velocity Plots. The preceding paragraph outlines a graphical procedure for evaluating the impact pulse shape obtained in a test where the pulse shape differs from the shape of an isosceles triangle. While this procedure is based on graphical concepts, a

digital listing of the acceleration and velocity generated during the impact, for every millisecond (0.001 second) of time during the impact, should be used to obtain an accurate evaluation. To illustrate this procedure, consider the transport airplane impact pulse and velocity plots shown below:

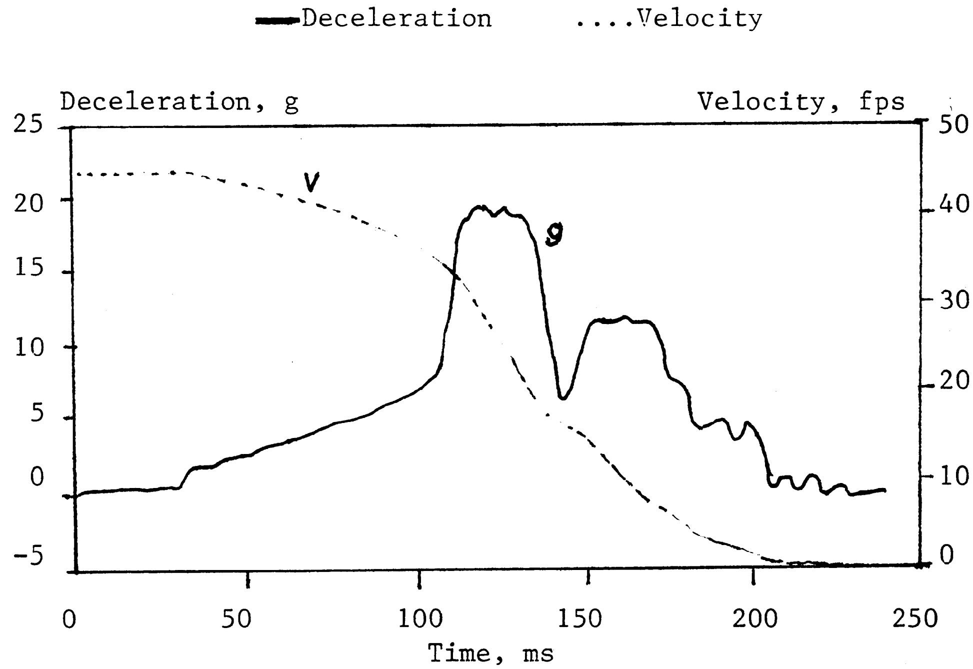


FIGURE 7

a. In Figure 7 the deceleration (negative acceleration) data are shown plotted by the dark line to correspond to the scale at the left. Since this is a deceleration test, the velocity decreases during the test as shown by the dashed line which corresponds to the scale on the right. The purpose of the test was to provide the environment required for Transport Airplane Test 2, similar to Figure 1 Test 2 position of this AC, namely an impact pulse with the shape of an isosceles triangle with a maximum rise time of 90 ms (milliseconds), a peak deceleration of at least 16 g, and an impact velocity of at least 44 fps (feet per second). From the digital listing of the data, it was found that the peak deceleration was 19.43 g and the overall velocity change during the impact was 44.1 fps. However, the shape of the impact pulse does not correspond to the ideal shape of the isosceles triangle. The procedure described in Chapter 2, paragraph 2, will be used to determine if this impact pulse generated an acceptable equivalent to the ideal isosceles triangular shaped pulse and to the conditions which were based on that ideal pulse shape.

b. First, construct the 0 g calibration base line (1 in Figure 8) and locate the peak deceleration (G_p). The data showed that the peak deceleration of 19.43 g occurred at 117 ms.

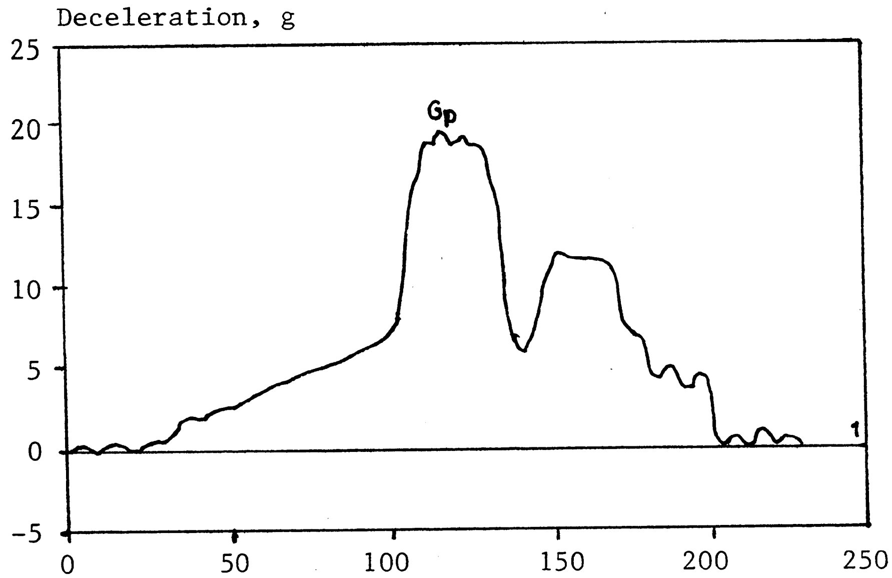


FIGURE 8

c. Next, construct lines parallel to the base line, through G_p and at levels of 0.9 G_p (17.49 g) and 0.1 G_p (1.94 g), shown as lines 2, 3, and 4, respectively, in Figure 9.

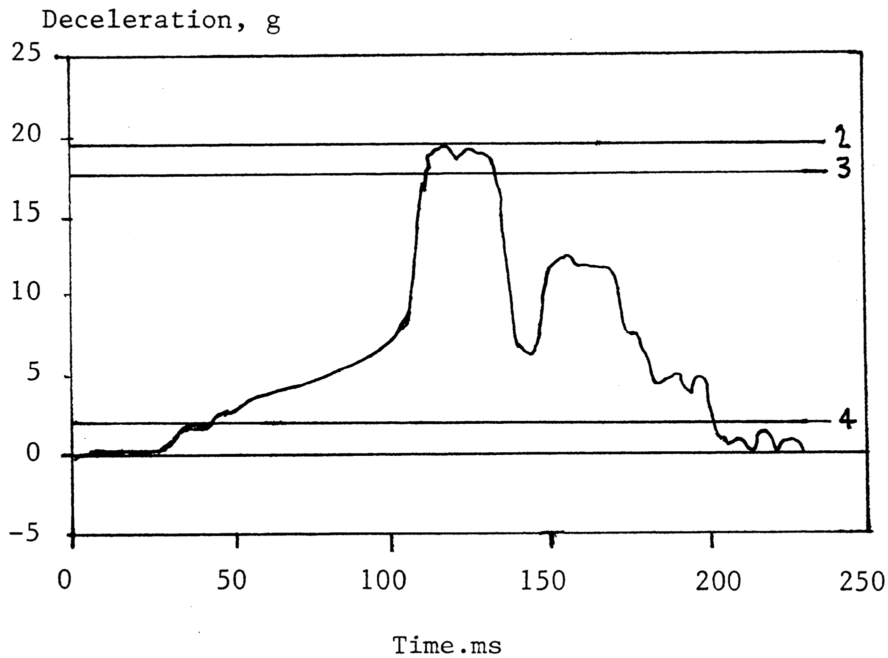


FIGURE 9

d. The next task is to construct an onset line through the intersection of lines 3 and 4 with the deceleration curve. The data showed that the deceleration reached 1.94 g at a time of 44ms, and 17.49 g at 110 ms. These points are identified as "a" and "b" in the figure below, and the onset line is identified as "5". The onset line should be extended until it intersects the G_p line (at point "d") and the base line (at point "c"). These intersection points can be calculated by finding the slope of the onset line:

$$\text{Slope of onset line} = (17.49 - 1.94)/(0.110 - 0.044) = 235.6 \text{ g/s}$$

The time between points "c" and "a" or between points "b" and "d" is then found by dividing the g interval between those points by the slope of the onset line, or 1.94/235.6 = 0.008 s. This time is subtracted from the time of point "a" to obtain the time of point "c". In this manner, we find that the 36 ms and the intersection of the onset line with the line through G_p takes place at (110 + 8) or 118 ms. Note that this latter time will not normally coincide with the time of G_p. The difference between these two times is the rise time, t_r, as referenced in Figure 1 of this AC. Thus t_r is equal to 82 ms, which is the distance between points "c" and "e" in Figure 10.

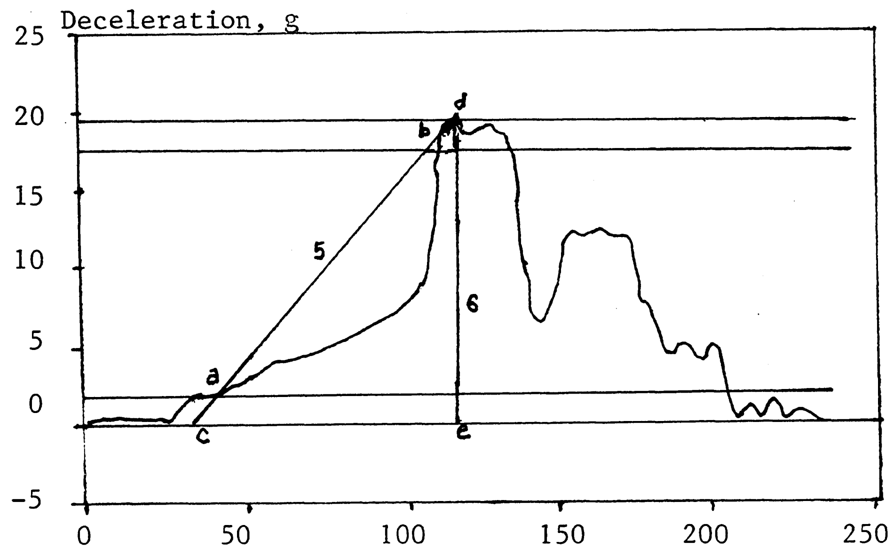


FIGURE 10

e. The area under the data plot from the beginning of the rise time (36 ms) to a time 90 ms later (36 + 90 = 126 ms) represents the velocity change during the period identified as t_r in Figure 1. It can be obtained by integrating the area under the curve between these times (multiply by 32.17 to change "g" to fps^2). Alternatively, from the velocity data listing, it was found that the velocity at 126 ms was 22.52 fps, and the velocity at 36 ms was 43.69 fps, so that the velocity during the rise time was 43.69 - 22.52 = 21.17 fps. In a similar manner, the area under the data plot from the beginning of t_r (point "c") to a time 207 ms (i.e., 2x90 + .03x90) later represents the effective velocity change of the impact pulse. It can be found by integrating the area under the curve from 36 ms to 243 ms or from the velocity data. The data showed that the velocity at 243 ms was only 0.003 fps, so that the effective velocity is 43.69 - 0 = 43.69 fps.

f. The results of applying this procedure to the impact pulse chosen for this example are summarized in Table 1.

Comparison of a Measured Impact Pulse
With Impact Pulse Designated for Test 2
Transport Airplanes

Measure	*Designated	Calculated
Peak g, G_p	At least 16 g	19.43 g
Rise time, t_r	Not more than 0.09 s	0.082 s
Velocity Change During Time Rise	At least 22 fps	21.17 fps
Velocity change	At least 44 fps	43.69 fps

Note: * Reference § 25.562(b)(2).

TABLE 1

g. It can be seen that the velocity change in Table 1 during the rise time of the impact pulse used in this example for a transport airplane is inadequate. Since the response of the seat, restraint, and occupant is sensitive to the rate at which the system is exposed to the impact energy, the example pulse would not be acceptable for the test as described. It is also noted that the total effective impact velocity is also insufficient for the test, even though the overall impact velocity change was greater than the designated minimum. If the impact test facility characteristically produces an impact with a relatively long duration low level "g", either immediately prior to or following the main impact pulse, the rise time to achieve the change in velocity will probably be insufficient.

3. Figures 11 and 12. Figure 11 is an example of a rotorcraft impact pulse for purely vertical deceleration dynamic impact test. This figure and the previous figures illustrate the difference between rotorcraft vertical impact pulse and the transport airplane longitudinal pulse. Figure 12 presents the ATD lumbar (spinal) load associated with this vertical deceleration impact.

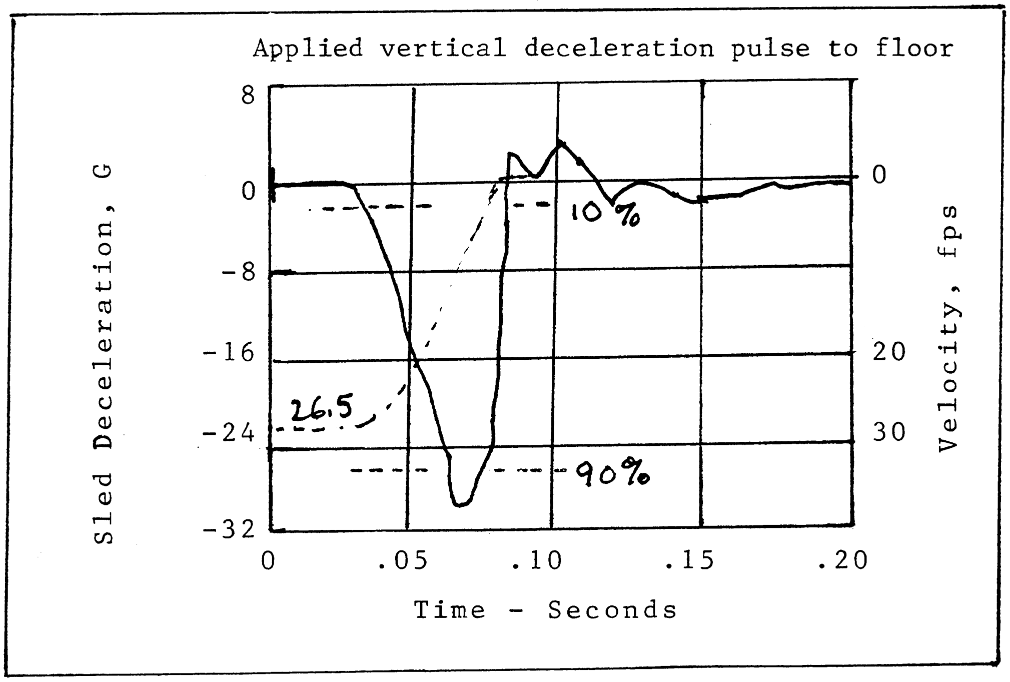


FIGURE 11

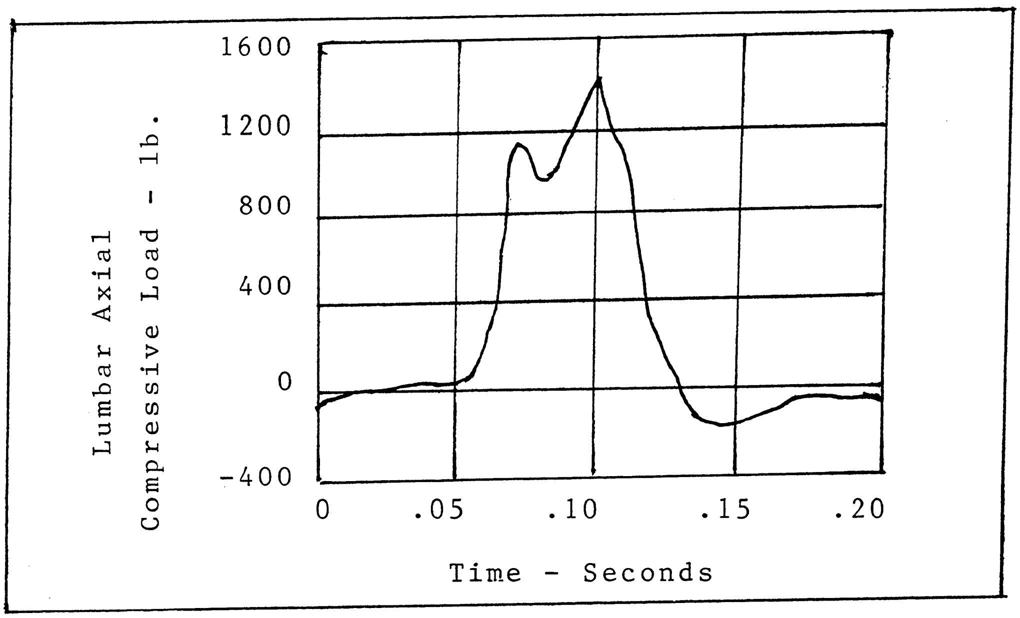


FIGURE 12

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